

Application of Neural Networks to Industrial Diagnosis of an Agro-Alimentary production System

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Abstract

The objective of this paper, is to conceive and carry out a system of assistance to the diagnosis of the failures by RBF networks applied to an agro-alimentary production facility. The training base is generated, not by modeling in the state space, but by the use of the failure modes analysis of their effects and their criticality (FMEAC).

The goal of this paper consists in developing a diagnosis system of the failures in the level of production facilities by using the techniques of training by gradient back-propagation and probabilistic networks belonging to the family of the networks with basic radial function (RBF). The originality lies in the fact that for these techniques the training base is generated by the use of the failure modes analysis of their effects and their criticality FMEAC).

1. Introduction

The goal of this paper consists in developing a diagnosis system of the failures in the level of production facilities by using the techniques of training by gradient back-propagation and probabilistic networks belonging to the family of the networks with basic radial function (RBF). The originality lies in the fact that for these techniques the training base is generated by the use of the Failure Modes and Effect Analysis (FMEA) [Davallo E ; Naim P. 1989].

Our objective through the diagnosis systems design is to help the operators of the dairy of AURÈS in their tasks of detection and diagnosis of the failures occurring on the level of the system of pasteurization of milk and to contribute to their resolution.

2. Industrial Application : Pasteurization unit

2.1. Introduction

A first application relating to the unit of crushing was used to put forward the usefulness of a failure analysis technique, in fact the FMEA for the construction of our training base. Two techniques of training were used: the back-propagation training of the gradient and the training by probabilistic networks belonging to the family of the networks with basic radial function (RBF). The training base is then generated by the use of the FMEA. These two training techniques enable us to choose the algorithm which gives the best results of classification for our application.

2.2. The neural network system

Among the essential components to the operation of the operational tool, the sensors placed on the level of the various parts of the industrial process allow the on-line extraction of information. A central processing unit of the extracted data (a computer in which the calculation algorithm and the training base are stored). An interface of adaptation of information (digital-analog conversion unit), and an interface of communication between the machine and the user. The originality of this search lies in the exploitation of a method of analysis of reliability for a diagnosis containing neural networks. In the phase of network training, the whole input vectors are built starting from the FMEA.

2.3. Description of the process

Our study relates to the subsystem corresponding to the pasteurizer group intended for the dairy products (figure 1). It is made up mainly of a system of control, a reserve of balancing (vat on constant level), an exchanger of heat to plates having four sections, two pumps, of the valves and the pipe of connection.

At the time of its starting, the circuit must be balanced by a water supply. When the temperature of pasteurization is reached at the exit of the section of heating, and that the temperature at the exit of the section of refrigeration is of 4-6 °C, the product can be introduced once that the water level is at least in the vat on constant level.

The product coming from the storage tanks is aspired in the vat to constant level to supply the exchanger of heat to plates. It circulates thus in the whole of the circuit under the action of the feed pump **M1**.

The by-pass valve **V4** is actuated so that milk crosses the section of pre-heating then passes directly in the section of heating, to reach a temperature ranging between 90°C and 95°C. The heating is ensured by the circulation of hot water in the section of heating via the pump **M2**. this water is by the vapor provided by the valve **V2**.

The temperature regulator **TC** carries out the adjustment of the valve of ordering of the vapor. At the exit of the exchanger of heat, if the temperature goes down below the fixed value (90°C), the valve of return **V1** ordered by the controller of temperature **TSL** is actuated to allow the return of the product towards the reserve of balancing. It circulates there again until its temperature is in the tolerated margin (90°C – 95°C). A light warming starts indicating to the operator a problem of temperature.

The circuit must be balanced by the penetration of the cold. Thus, the temperature at the exit of the section of cooling (where circulates frozen water) is regulated manually via the valve **V3**. In this phase a regulator from which receives the temperature of exit of the milk of the transmitter will proceed to what follows: If the temperature of the product at the exit is lower than 4°C, the controller of temperature of exit will activate the valve **V5** for the return of milk in the vat of balancing, if it is higher than 6°C thus

the product is not well cooled, milk will be forwarded to the exchanger of heat for a new cooling. If the temperature of the product is in the margin of pasteurization ($4^{\circ}\text{C} - 6^{\circ}\text{C}$) milk is directed towards the exit of the system of pasteurization.

The outgoing product is led towards the lines of conditioning. A voltmeter indicates the quantity of the treated product.

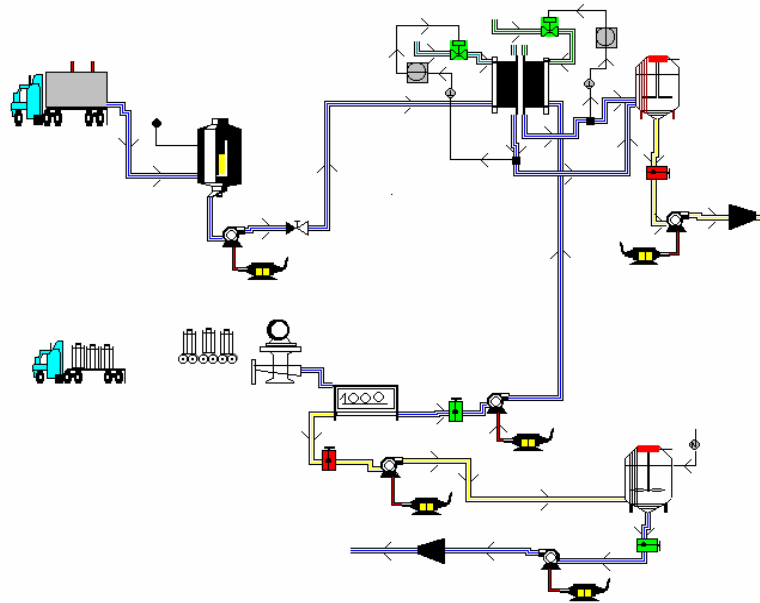


Figure. 1: Pasteurization process.

2.4. Diagnosis system

2.4.1. Context of use and objective

In what follows we will analyze initially the context in which must be integrated the diagnosis system, as well as the method of analysis used, then we will develop the methodological aspects which make it possible to work out a solution which answers the needs and stresses of the exploitation of the process in which we are interested [Zwingelstein G.1995] [M'Hamed Yebou, Y. 1998].

a) Context of use

For the realization of the failure diagnosis system by neural networks, it is imperative to take into account some problems involved in the exploitation, the diagnosis and the stresses related to the process and the future users. Our diagnosis system implemented on microcomputer must be placed at the disposal of the personnel in charge of maintenance, and can be installed meadows or moved away from the equipment to control. Thus, the diagnosis system can operate in real-time and its operation requires the use of several interfaces allowing the adaptation and the data processing batches by the equipment to be controlled, and the man/machine communication.

b) Objective

The objective of the realization of a diagnosis system of abnormal operations compared to the existing means (wiring diagrams, measuring instruments, manuals of repair, etc.) is to allow an effective assistance of a precise identification of failure modes and their possible causes.

Our diagnosis neural system is used as a methodological support and complementary to the experiment available to the maintenance men and the operators of control.

The elaborated system is an on line diagnosis system ensuring the reliability of the production facility. The user is informed by the diagnosis system by: electronic mail, or by audible or visual alarms, etc.

2.4.2.Realization

The realization of our diagnosis neural system passes by the following steps:

- Modeling of the industrial process,
- Definition of the neural network architecture,
- Choice of the adopted algorithm,
- Creation of the training base starting from the analysis model,
- Training of the diagnosis system (neural networks).

Among the essential components for the operation of the operational tool,

- the sensors placed on the level of the various parts of the industrial process, allow the on-line extraction of information;
- a central processing unit of the extracted data (a computer in which the calculation algorithm and the training base of are stored);
- an information adaptation interface (digital-analog conversion unit), and a communication interface between the machine and the user. [Coiton J, Gilhodes J. C, Velay J. L. and Roll J. P 1991]

a) Development strategy

The field of the reliability offers various methods facilitating the diagnosis of the industrial systems. However, it is significant to take into account of the requirements to which the diagnosis system must answer to guarantee the effectiveness of our choices. We found judicious to exploit the AMDE method for neural networks diagnosis. In the network training step, the whole vectors of input is built starting from the AMDEC.

b) The FMEA method

The FMEA is a method of critical analysis which consists in identifying in an inductive and systematic way the risks of abnormal operations of a system then to seek the origins and their consequences. More generally, it allows:

- Identification of the failure modes of all the components of a system;
- The possible investigation into the failure causes, for each mode of failure;
- The evaluation of the effects on the system and the user for each combination cause-mode of failure;
- The search of possible detections, for each combination cause-mode of failure.

The FMEA was always used for the studies of the diagnosis prepared within the framework of the plant maintenance. The diagnosis uses the links between the effects of a failure, perceived like a deterioration of a function of the system, and causes at the origin of this failure. It is carried out by addition of detection tests (visual or sound alarms, measurement of signals, etc.) allotted to each combination cause-mode of failure (figure 2) [Villemeur A.1998].

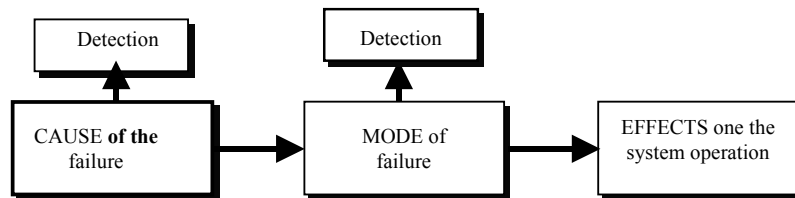


Figure. 2: Failure mechanism

The realization of an FMEA first of all requires the determination of the level of decomposition. A system could be the subject of a hierarchical decomposition in as much of level than it will be necessary. The last level corresponds in general to the last replaceable component, the level of decomposition must be compatible with the knowledge of all the modes of failure, and their effects. The results of these analyses are then presented in the form of a table with columns gathering the main analyzed criteria.

2.4.3. Generation of the training base

As known, the inputs of a neural network are specific to each studied system, a pretreatment of the data must be made in order to lead to the construction of a training base.

In our application, the inputs of the network are the effects on the elementary systems composing the whole system, and which are in the form of binary vectors (compounds of 0 or 1). These vectors make the result of a binary coding on collected information of AMDE tables. After coding that we adapted for the data pretreatment, we arrived at two matrix: [Touzet C et O. Sarzeaud O 1992].

- Matrix of inputs of the network $E_{m \times n}$ consisted of the effects on the system.
- Matrix of desired exits $S_{m \times m}$ of the network, which represents the failures modes and the possible causes.

The matrix of input $E_{m \times n}$ is an interpretation of a two dimensions table such as m represents the number of possible modes of failures and n represents the number of the possible effects on the system.

Table 1 represents the coding of the data extracted starting from the FMEA of our system from pasteurization.

3. Conclusion

The FMEA is particularly useful for the diagnosis of operational systems. If it were well made, it contains all the possible failures connected to their causes. The problem of the diagnosis is then the deductive step which consists in analyzing the table and to determine all the possible causes of an observed failure. The advantage of this method, which is its exhaustiveness in the determination of the links of cause to purpose, becomes also a disadvantage: its extreme heaviness of use. For complex industrial systems, an

FMEA can lead to the realization of thousands of tables. Under these conditions, the use of the FMEA for the diagnosis imposes the use of a deductive procedure which makes it possible to automatically generate knowledge necessary to the design of a diagnosis tool.

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Effect Model	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
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16	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
20	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1

Table1 : Interpretation and code of extract data of FMEA